Flame Resistant Officers and Chief Petty Officers Work Uniform Evaluation

Navy Clothing and Textile Research Facility
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The Navy Clothing and Textile Research Facility evaluated potential commercially available fire retardant(FR) candidate replacement fabrics for the Navy's 65/35 polyester/cotton poplin khaki shirt and twill trouser fabrics, for application in all officer and Chief Petty Officer(CPO) khaki shipboard work uniforms. Based upon user preference, durability and flame protection data, the recommended flame resistant working uniform for officers and CPO's is the inherently FR 55/45 Fibrous Flame Retardant/cotton blended shirting and trouser materials, commercially known as "Firewear".

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BACKGROUND

In 1985, the Navy Clothing and Textile Research Facility (NCTRF) was tasked by the Naval Sea Systems Command (NAVSEA 03G) to develop a flame resistant (FR) work uniform for Chief Petty Officers (CPO) and Commissioned Officers to replace their polyester/cotton shipboard work uniform. This action was in support of Navy Decision Coordinating Paper (NDCP) No. S-1121-SL/20APR 1980, which required that all shipboard clothing be flame resistant. Based on the NDCP, a FR chambray/denim utility uniform for enlisted personnel was developed in 1983 and an FR coverall for engineering spaces was introduced in 1987.

Although technical data and user preference recommended a Nomex^{R} shirt and trousers to replace the khaki two-piece working uniform at that time, the uniform was never introduced into the fleet because of the high cost of Nomex^{R}. Since that time, technology in the area of flame resistant materials has continued to evolve in a positive fashion and new fabrics at lower costs have become available.

INTRODUCTION

As a result of an October 1993 Flag Level Safety and Survivability Action Team Meeting, NCTRF was once again tasked, under the guidance of the Chief of Naval Operations (OPNAV N86D) and NAVSEA (03G), to re-evaluate the FR CPO/Officers work uniform. The goal was to take advantage of new FR finishes and fibers that had evolved since the 1985 effort. This new technology provided the opportunity to develop a protective FR work uniform that was lower in cost, functional, durable, and thus was better suited for the shipboard environment.

APPROACH

In July 1994, an evaluation was initiated comparing two FR khaki uniforms. The uniforms are similar in design to the current khaki polyester/cotton shirt and trouser worn by officers and CPOs. A 100% fire retardant treated (FRT) cotton and a 55/45 Fibrous Flame Retardant (FFR)/cotton blend, commonly known as "Firewear", were selected and fabricated into uniforms. These materials were down-selected from other commercially available fabrics, because they were cost effective and successfully met the flammability requirements of the National Fire Protection Association's (NFPA) Station/Work Uniform standard, 1975, 94 revision. The FRT cotton and Firewear materials were manufactured by Westex and Springs Protective Fabrics, respectively. Because candidate uniforms were intended as a replacement for the current (non-FR) long sleeve polyester/cotton khaki blend uniforms, the materials evaluation and ship wear trial were to be conducted as a comparison only between the two candidate FR uniforms in order to select the uniform offering the best overall performance for wearability, durability and launderability.

FABRIC EVALUATION

FABRIC DESCRIPTION

The shirting candidate fabrics targeted a weight of 5.5 oz/sq yd and the trouser fabrics targeted a weight of 9.0 oz/sq yd. These weights represented what was currently available commercially for top and bottom weights. Table I provides a general description of the candidate fabrics.

The fabric properties indicated in Table I (weave, thickness and yarns per inch) are basic descriptors for materials, and are measured during testing as a means of verifying desired quality levels. A brief description is provided for each of these properties: weave is a system or pattern of intersecting warp and filling yarns; thickness is the distance between the upper and lower surfaces of the material, and is measured randomly under a specific pressure; and yarns per inch is an average of the number of warp and filling yarns present in an inch of fabric.

Westex's "Indura" Proban durable 100% FRT cotton fabrics have been engineered to acquire their fire retardant properties from a topical phosphorous treatment. The FR chemical is applied in a pad on process and subsequently cross-linked by an ammonia vapor cure within the interstices of the cotton fiber. "Indura" fabrics are designed to self extinguish after limited flame impingement, by releasing phosphorous and nitrogen eliminating the oxygen supply, thus smothering the flame.

Springs Protective Fabrics's "Firewear" line of inherent FR fabrics consists of an intimate blend of 55/45 FFR and cotton. FFR is a chemically modified modacrylic that is designed not to melt drip. FFR fibers behave as a vapor-phase flame retardant when exposed to heat, releasing non-combustible gasses through microscopic pores in the fiber, eliminating the oxygen supply and, like FRT cotton, smothers the fire.

TEST PROCEDURES

With the exception of vertical flammability, all fabric testing was completed in-house at NCTRF. Due to the renovation of the flammability laboratory, all vertical flammability testing was contracted to a commercial testing facility, Springboard Labs.

The test procedures employed in evaluating the candidate materials for physical, flame resistance, dimensional stability, and thermal/water vapor resistance characteristics are summarized in Table II.

Weight, tear strength, and flame resistance were performed on each of the candidate fabrics initially, and after 25, 50, 75, and 100 shipboard launderings. The multiple launderings were conducted in accordance with the Shipboard Formula II procedure from Naval Education and Training Manual 10176/90. An outline of this procedure is provided in Appendix - A.

Weight measures both the initial weight of a fabric and the loss of fabric weight following repeated launderings. For this evaluation, it was used as a factor in assessing durability of the candidate fabrics.

TABLE - I

GENERAL CHARACTERISTICS OF CANDIDATE MATERIALS

SUPPLIER	WEIGHT (oz/sq yd)	BLEND (%)	CONSTRUCTION (WEAVE)	YARNS PER INCH W/F	THICKNESS (INCHES)	FIRE RETARDANT FINISH
WESTEX INC.	6.1	100 Cotton	Oxford	131/44	.013	Precondensate/ Ammonia Cured
	9.9	100 Cotton	3/1 Left Hand Twill	92/45	.019	Precondensate/ Ammonia Cured
SPRINGS PROTECTIVE FABRICS	5.7	55/45 FFR/Cotton	Plain	64/48	.014	Inherent
	9.4	55/45 FFR/Cotton	2/1 Right Hand Twill	85/54	.021	Inherent

W - Warp Direction
F - Filling Direction

TABLE II

CANDIDATE MATERIAL TEST PROCEDURES

Characteristics	Test Method*
Weave	Visual
Yarns/inch	5050
Weight After 100 launderings (25 cycle intervals)	5041 & NAVEDTRA 10176 shipboard formula II
Tear strength After 100 launderings (25 cycle intervals)	D1424-83/ASTM & NAVEDTRA 10176 shipboard formula II
Flame resistance After 100 launderings (25 cycle intervals)	5903 & NAVEDTRA 10176 shipboard formula II
Thickness	5030
pH	2811
Stiffness	5202
Colorfastness to Light (40 SFH)	5660.1
Colorfastness to Laundering (3 cycles)	5610.1
Colorfastness to Perspiration	5680
Colorfastness to Crocking	AATCC-8-1989
Colorfastness to Dry Cleaning	5621
Flat Appearance	AATCC-124-1992 (1 & 5 cycles) procedure (1) normal IV, Aiii
Dimensional stability	5550
Thermal & Water Vapor Resistance	ISO 11092

*Federal Standard for Textile Test Methods 191A (with amendments) was used except where otherwise noted
AATCC - American Association for Textile Chemists and Colorists
ASTM - American Society for Testing & Materials
ISO - International Standards Organization

Tear Strength is defined as the force that is required to continue a tear or rip already started in a fabric.(1) Repeated testing measures the loss of strength after multiple launderings. For this evaluation, it was used as a factor in assessing durability of the candidate fabrics.

Flame Resistance is assessed by subjecting candidate fabrics to a vertical flammability test. In this evaluation, unlaundered and multiple-laundered samples were subjected to a 12 second flame exposure in order to determine any loss in flame resistance due to laundering. Samples were measured for after flame, afterglow and char length. This laboratory scale screening test indicates a fabric's ability to self-extinguish and maintain integrity after exposure. Pass/fail criteria, consisting of a maximum 2 second after flame and a maximum six inch char length, were used to compare all flammability test results. These criteria are required by the NFPA Station Work (utility) Uniform 1975, 94 revision standard. Commercial standards are targeted for all protective clothing whenever possible.

pH indicates the acidity or alkalinity of a material.(2) Military and federal material specifications generally require a pH level between 5 and 8.5.

Stiffness indicates the fabric's resistance to bending, thus providing some measure of draping qualities.

Colorfastness measures the affinity of a dye when subjected to a specific condition. It refers to the dyestuff's resistance to fading, or its color retention, when exposed to various conditions such as sunlight, abrasion, perspiration etc.

Flat appearance evaluates the smoothness of fabrics after laundering. As required by the test method, appearance is determined by subjecting candidate fabrics to a normal home laundering/tumble drying procedure, then comparing their appearance to a three dimensional durable press replica. A replica exists for each of the ratings below. Ratings are assigned by three independent observers and then averaged. The rating scale is as follows:

1. Crumpled, Creased, and Severely Wrinkled Appearance
2. Rumpled, Obviously Wrinkled Appearance
3. Mussed, Non-pressed Appearance
4. Smooth Finished Appearance
5. Very Smooth, Pressed, Finished Appearance

Dimensional Stability is defined as the ability of a textile material to maintain or return to its original geometric configuration.(3) It measures the increase (elongation) or decrease (shrinkage) in the length or width of a fabric after it is subjected to an accelerated laundering method. The normal military and federal specification limits for shrinkage and elongation are between 2 and 3%.

Thermal Insulation and Evaporative Heat Transfer assess the ability of a fabric to transfer heat and water vapor, respectively. They provide an indication of the fabric's ability to maintain thermal comfort in various environments. To maintain comfort and maximize body heat loss in a warm environment, both a low thermal resistance (i.e., low insulation) and low water vapor resistance (i.e., high water vapor permeability) are desirable.

DATA ANALYSIS

Results for stiffness and tear strength were statistically analyzed using a one-factor and two-factor analysis of variance, respectively. Significance was accepted at $p \leq 0.05$. Tukey's test for multiple pairwise comparisons was performed as a follow-up.

Differences in other physical test parameters were evaluated in accordance with either appropriate test methodologies or standard industry practice.

RESULTS

Weight - Results for weight are provided in Table III. Initial weight of candidate fabrics were within $\pm$ 10 percent of their target; 5.5 ounces per square yard for shirting and 9.0 ounces per square yard for trousers.

After 75 launderings, the FRT cotton shirting fabric lost over 30 percent of its original weight, exhibiting a consistent decline in weight with increasing number of launderings. The FRT cotton shirting fabric lost its integrity after 100 launderings, and could not be tested. (It should be noted that during the laboratory evaluation of both FRT cotton fabrics, substantial amounts of fiber clogged the drainage system of the laundering equipment. This phenomenon was not experienced with the Firewear products.)

In evaluating the Firewear shirting, the weight increased after 25 and 50 launderings due to shrinkage of the fabric during laundering which resulted in an increased density of the fabric. There was no weight loss experienced up to 100 shipboard launderings.

The FRT cotton trouser fabric experienced a 19 percent weight reduction after 100 shipboard cycles, exhibiting a consistent weight decline with multiple launderings.

The Firewear trouser fabric increased in weight when tested after 25, 50, 75, and 100 launderings, gaining slightly over three percent after the 100th cycle. Like the Firewear shirting, this was attributed to shrinkage of the fabric.

Overall, results indicate that the FRT cotton fabrics consistently lost weight throughout repeated launderings while the Firewear fabrics gained weight due to shrinkage and then lost weight gradually through repeated launderings.

Tear Strength - Results for tear strength are reported in Table IV. Tear strength results are analyzed separately for the warp and fill. For the FRT cotton shirting fabric, results indicate a consistent decline in tear strength from the initial warp and fill values with increasing number of launderings. Significant decreases in tear strength after each successive test are noted except between the initial value for the fill direction and the "after 25" launderings measure. The FRT cotton shirting was not tested after 100 launderings because the fabric disintegrated and was unable to be tested.

For the warp direction of the Firewear shirting fabric, the initial tear strength was significantly higher than after 25, 50 and 75 launderings. There were no significant differences among the tear strengths measured after 25, 50 and 75 launderings. Likewise, for the fill direction of the Firewear shirting, the initial tear strength was significantly higher than after 25, 50, and 75 launderings. Strength after 25 launderings was also significantly higher than after 50 or 75 launderings. However, there was no significant difference between the results after 50 and 75 launderings.

For the FRT cotton trouser fabric, results again indicate a consistent decline in tear strength from the initial warp and fill values with increasing number of launderings. Tear strength in the warp direction significantly declined after each successive series of launderings; in the filling direction, tear strength significantly decreased until 75 launderings, after which it did not change.

Evaluating the Firewear trouser fabric before and after laundering, the initial tear strength is significantly higher than all post-laundering values in both the warp and fill directions. Also, the tear strength in the warp direction after 25 launderings is significantly higher than after 50, 75 and 100 launderings.

Overall, results show that the FRT cotton continuously loses tear strength and degrades with successive launderings. In contrast, the Firewear loses significant tear strength during the first 25 launderings but then tends to level off with respect to strength.

Flammability - As indicated in Table V, the FRT cotton fabrics failed flammability sometime after the 50th cycle for the shirting material and sometime after the 75th cycle for the trouser fabric. Both Firewear shirting and trouser candidate fabrics successfully met the criteria for flammability initially and after 100 launderings.

All results for pH, stiffness, colorfastness, flat appearance, and dimensional stability, are reported in Table VI.

pH: - All of the candidate fabrics exhibited acceptable results for this property, falling between the specified 5 to 8.5 range for all military and federal material specifications.

Stiffness - For both the warp and fill directions, the FRT cotton shirting fabric was significantly stiffer than the Firewear fabrics. Likewise, for both the warp and filling directions, the FRT cotton trouser fabric was significantly stiffer than the Firewear fabrics.

Colorfastness - All candidate fabrics exhibited satisfactory results for colorfastness to perspiration, crocking (rubbing) and dry cleaning. The normal specification requirements for colorfastness to perspiration/dry cleaning and crocking is a minimum "good" rating and a minimum 3 (wet and dry) rating, respectively. With the exception of the "good" rating for colorfastness to laundering for the FRT cotton trouser fabric, all candidate fabrics were rated "fair" or "poor" for both light fastness and laundering. This deficiency appears to be an inherent problem with all of the FR fabrics.

Flat Appearance - Both FRT cotton shirting and trouser materials received the lowest rating of 1 for flat appearance, possessing a crumpled, creased and severely wrinkled appearance. The Firewear fabrics showed better performance for this property, with the ratings after five cycles (2.5 for the shirt and 2.8 for the trouser fabrics) indicating an appearance between unpressed and obviously wrinkled finish.

Dimensional Stability - With the exception of the Firewear shirting fabric, all candidate fabrics were within the desired maximum of 3% shrinkage. Shrinkage of the Firewear shirting in the filling direction was 3.6%. In general, shrinkage of Firewear material was observed to be slightly greater than FRT cotton materials.

Thermal Insulation and Evaporative Heat Transfer - Table VI also presents the results of the guarded hot plate tests for thermal insulation and moisture vapor permeability. The thermal insulation values for the two fabrics are presented in clo units. The higher the clo value the higher the thermal insulation, or resistance to heat transfer. The measurement of evaporative heat transfer is presented in terms of the moisture permeability index, i_m, which is dimensionless. The higher the i_m, the greater the water vapor transfer through the fabric. The ratio of i_m/clo reflects the total heat loss through the material taking into account both thermal insulation and evaporative heat loss. A lower number indicates a potentially higher level of heat stress.

Because test instrumentation like the guarded hot plate has such little inter-test variability, statistical significance between various fabrics is relatively easy to show. However, the significance of these differences is not always operationally - or noticeably - different to the wearer. A more practical method for analyzing the data is to use an arbitrary difference for concluding that materials are better or worse than each other or when compared to standard materials.

The U.S. Army Research Institute of Environmental Medicine has suggested that for most applications, 10% difference in clo or i_m could be used for evaluating whether fabrics differ from each other.(4) Items that are within $\pm$10% of each other are considered equivalent. Items with thermal properties outside this 10% range are considered different.

Comparing the FRT cotton and Firewear fabrics, the clo values of the shirting fabrics are .50 and .45, respectively; and the clo values for the trouser fabrics are .49 and .44, respectively. In both cases, the FRT cotton value is slightly more than 10% higher than the Firewear value. Because it is more insulative, the FRT cotton is considered to be inferior to the Firewear for this parameter. It would, therefore, be expected to be warmer for a user at a low activity level or in a comfortable environment where no sweating would occur.

Comparing the FRT cotton and Firewear shirting fabrics, i_m/clo ratios are 1.31 and 1.32, respectively and are considered equivalent. Likewise the FR Cotton and Firewear trouser fabrics have i_m/clo values of 1.07 and 1.11, respectively and are considered equivalent. This indicates that for a user who may be sweating because of heat and/or activity level, the two candidate fabrics should be able to provide equivalent rates of total heat loss .

DISCUSSION AND CONCLUSION

Based on compiled data, the Firewear fabrics appeared equal to, or better than the FRT cotton materials for most performance tests. In terms of durability, the FRT cotton materials suffered a greater weight loss than the Firewear materials after successive launderings, to the point where the FRT cotton shirting materials lost its integrity after 75 launderings. Although only the weight of the Firewear fabrics increased after multiple launderings, it was assumed that the FRT cotton fabrics may have increased in weight, as well, if excessive fiber loss had not occurred. This fiber loss was demonstrated in the laboratory, where excessive amounts of fiber clogged the filters of the laundering equipment. The weight loss of FRT cotton materials had a direct effect on its tear strength. The FRT cotton showed a consistent decline in tear strength to the point where the shirting fabric, as mentioned before, fell apart after 75 launderings. The Firewear materials showed a decline in tear strength after 25 launderings, but generally retained their strength thereafter.

The fiber loss suffered by the FRT cotton materials could also be linked to failures in Flame Resistant performance, where the FRT shirting and trouser cotton materials, failed flammability after 50 and 75 launderings, respectively. The Firewear materials demonstrated acceptable performance through 100 launderings.

Fabric weight, stiffness, thermal insulation, and evaporative heat transfer of materials contribute to the perceived comfort of the garment. In examining the test data, the weight of both the FRT cotton and Firewear materials, for both shirts and trouser, were approximately the same. Stiffness, on the other hand, showed the FRT cotton materials to be

significantly stiffer than the Firewear materials. Likewise, the FRT cotton fabrics are slightly more insulative and would feel warmer to the individual at a low activity level. This difference becomes insignificant, however at higher activity levels when evaporative cooling becomes important. For these conditions, the two candidate fabrics are equal.

Appearance of the materials was based on flat appearance and colorfastness. Test results for flat appearance showed that the Firewear materials wrinkled after laundering, but not as severely as the FRT cotton materials. With respect to colorfastness, laundering and light appeared to be a problem for both the FRT cotton and Firewear materials. This is a noted problem of all commercial available flame resistant materials today.

In conclusion, test results showed the Firewear materials to perform better than FRT cotton fabrics for fabric durability, flame resistance, and appearance. Comfort was judged to be equal for both candidate fabrics based upon thermal insulation and evaporative heat transfer.

TABLE III

WEIGHT (OZ/YD2) OF CANDIDATE FABRICS AFTER MULTIPLE LAUNDERINGS FEDERAL STANDARD 191A - TEST METHOD 5041. (Values represent the mean of five replications).

	SHIRTING FABRICS		TROUSER FABRICS	
LAUNDERING METHOD	**FR-COTTON KHAKI-OXFORD 5.5 OZ.**	**FIREWEAR KHAKI-PLAIN 5.5 OZ.**	**FR-COTTON NAVY-TWILL 9 OZ.**	**FIREWEAR KHAKI-TWILL 9 OZ.**
SHIPBOARD FORMULA II	**140°F**			
INITIAL	6.1	5.7	9.9	9.4
25 CYCLES	5.9	6.1	9.8	10.0
50 CYCLES	5.3	5.9	9.3	9.9
75 CYCLES	4.2	5.8	8.4	9.6
100 CYCLES	FAILURE*	5.7	8.0	9.7

*SAMPLES FELL APART IN LAUNDERING/UNABLE TO SUBJECT TO TESTING

TABLE IV

TEAR STRENGTH (LBS) OF CANDIDATE FABRICS AFTER MULTIPLE LAUNDERINGS AMERICAN SOCIETY FOR TESTING & MATERIALS - D1424-83. (Values represent the mean of five replications).

	SHIRTING FABRICS				TROUSER FABRICS			
LAUNDERING METHOD	FR-COTTON KHAKI-OXFORD 5.5 OZ.		FIREWEAR KHAKI-PLAIN 5.5 OZ.		FR-COTTON KHAKI-TWILL 9 OZ.		FIREWEAR TWILL-KHAKI 9 OZ.	
SHIPBOARD FORMULA II 140°F	WARP	FILL	WARP	FILL	WARP	FILL	WARP	FILL
INITIAL	3.2	2.7	3.9	4.9	7.8	10.1	6.4	6.9
25 CYCLES	2.7	2.8	2.1	1.9	4.8	6.9	3.5	3.4
50 CYCLES	1.4	1.5	1.9	1.6	3.3	4.6	2.7	3.0
75 CYCLES	0.8	1.1	1.8	1.4	2.3	3.6	2.6	2.7
100 CYCLES	FAILURE*		1.9	1.4	1.5	4.1	2.5	2.8

*SAMPLE FELL APART IN LAUNDERING/UNABLE TO SUBJECT TO TESTING

TABLE V

FLAME RESISTANCE OF CANDIDATE FABRICS AFTER MULTIPLE LAUNDERINGS
FEDERAL STANDARD 191A - TEST METHOD 5903

		SHIRTING FABRICS		TROUSER FABRICS	
LAUNDERING METHOD		**FR-COTTON KHAKI-OXFORD 5.5 OZ.**	**FIREWEAR KHAKI-PLAIN 5.5 OZ.**	**FR-COTTON KHAKI-TWILL 9 OZ.**	**FIREWEAR KHAKI-TWILL 9 OZ.**
SHIPBOARD FORMULA II	**140°F**				
INITIAL	W	PASS	PASS	PASS	PASS
	F	PASS	PASS	PASS	PASS
25 CYCLES	W	PASS	PASS	PASS	PASS
	F	PASS	PASS	PASS	PASS
50 CYCLES	W	PASS	PASS	PASS	PASS
	F	PASS	PASS	PASS	PASS
75 CYCLES	W	**FAIL**	PASS	PASS	PASS
	F	**FAIL**	PASS	PASS	PASS
100 CYCLES	W	**N/A***	PASS	**FAIL**	PASS
	F	**N/A***	PASS	**FAIL**	PASS

W - WARP
F - FILL

*SAMPLES FELL APART IN LAUNDERING/UNABLE TO SUBJECT TO TESTING

TABLE VI

PHYSICAL CHARACTERISTICS OF CANDIDATE MATERIALS.
(Values Represent Number of Replications in Accordance with Test Method).

		SHIRTING FABRICS		TROUSER FABRICS	
CHARACTERISTICS	***TEST METHOD**	**FR-COTTON 5.5 OZ.**	**FIREWEAR KHAKI 5.5 OZ.**	**FR-COTTON 9 OZ.**	**FIREWEAR KHAKI 9 OZ.**
pH	2811	7.9	5.7	7.0	6.3
STIFFNESS W (IN/LBS) F	5202	.006 .003	.001 .001	.007 .004	.001 .002
COLORFASTNESS					
LIGHT -(40 SFH)	5660.1	FAIR	POOR	POOR	POOR
LAUNDERING - 3 CYCLES	5610.1	FAIR	POOR	GOOD	POOR
PERSPIRATION - ACID ALKALINE	5680	 EXCELLENT EXCELLENT	 GOOD GOOD	 GOOD GOOD	 GOOD GOOD
CROCKING - DRY WET	AATCC-8- 1989	4.5 3.5	5.0 4.5	4.5 5.0	5.0 4.5
DRY CLEANING	5621	EXCELLENT	GOOD	EXCELLENT	GOOD
FLAT APPEARANCE (1 CYCLE) (5 CYCLES)	AATCC- 124-1992	 1.0 1.0	 2.6 2.5	 2.0 1.0	 3.0 2.8
DIMENSIONAL STABILITY (%) W F	5550	 1.0 0.9	 2.2 3.6	 0.7 0.2	 1.7 1.9
THERMAL INSULATION AND EVAPORATIVE HEAT TRANSFER:					
CLO		0.50	0.45	0.49	0.44
I_m	ISO 11092	0.65	0.59	0.52	0.49
I_m/CLO		1.31	1.32	1.07	1.11

W - WARP
F - FILL

*FED STD 191A (WITH AMENDMENTS) WAS USED EXCEPT WHERE OTHERWISE NOTED
AATCC - AMERICAN ASSOCIATION FOR TEXTILE CHEMISTS AND COLORISTS
ISO - INTERNATIONAL STANDARDS ORGANIZATION

UNIFORM EVALUATION

TEST SAMPLES

Men's and Women's long sleeve khaki shirts, trousers, and slacks of the same design as the current khaki polyester/cotton uniform were constructed from the candidate fabrics. Neither uniform possessed a durable press or crease resistant finish.

TEST PROCEDURES

A 120-day comparative uniform evaluation was conducted on twenty two ships (East and West Coast) to determine fleet acceptability. The Bureau of Naval Personnel (GMCM Montgomery, Code Bupers 333 - Navy Uniform Matters Office), Washington, D.C. assisted in designating the following ships to participate in this evaluation.

EAST COAST

USS CINCINNATI	(SSN 693)	USS ARLEIGH BURKE	(DDG-51)
USS SHENANDOAH	(AD-44)	USS SHREVEPORT	(LPD-12)
USS SCOTT	(DDG-995)	USS ATLANTA	(SSN-712)
USS WHIDBEY ISLAND	(LSD-41)	USS YELLOWSTONE	(AD-41)
USS THEODORE ROOSEVELT	(CVN-71)	USS AMERICA	(CV-66)
USS HOIST	(ARS-40)	USS FITZGERALD	(DDG-62)

WEST COAST

USS CONSTELLATION	(CV-66)	USS FORT FISCHER	(LSD-40)
USS DENVER	(LPD-9)	USS KINCAID	(DD-965)
USS JARRETT	(FGG-33)	USS COMSTOCK	(LSD-45)
USS ESSEX	(LHD-2)	USS CHANDLER	(DDG-966)
USS CALLAGHAN	(DDG-944)	USS CAPE COD	(AD-43)
USS CHANCELLORSVILLE	(CG-62)		

During the week of 17-21 July 94, a team of NCTRF personnel made arrangements at East and West Coast Naval Exchanges to outfit fleet participants with the FR khaki work uniforms. A total of 133 Officer/CPO personnel (124 males and 9 females) were selected, fitted, and briefed prior to the start of this user evaluation. Each test participant received one FRT cotton uniform and one Firewear uniform for the comparative evaluation. Limited garment alterations were made by the tailoring shops to permit hemming of the trousers and slacks only. Because of the limited nature of this user evaluation, a complete range of garment sizes was not available. Distribution of the uniforms issued to test participants is provided in Appendix B. Participants were requested to wear each of the uniforms over a 120-day test period, commencing 1 August 94.

Questionnaire forms (Appendix C) were provided to each participant to collect information relative to the following characteristics:

a. Number of times uniform worn.
b. Number of times shipboard laundering.
c. Fit after repeated laundering.
d. Appearance after repeated wear and laundering.
e. Durability.
f. Comfort.
g. Preference.

Full scale fire envelopment and garment flame impingement testing of the candidate fabrics in uniform configuration, is currently being conducted at the Naval Research Laboratory, Chesapeake Beach Detachment. An addendum report will be prepared regarding the performance of both tests.

RESULTS AND DISCUSSION

Eighty three percent of the test participants responded to the test questionnaire. One hundred four respondents were male and 6 were females. A summary of data from the questionnaires is presented in Table VII .

Fit - Fifty three percent of the participants perceived the Firewear uniforms to fit better than the FRT cotton uniforms after continual wear and launderings. Subjective comments, however, did not indicate any shrinkage reported in either uniform. For the most part, both types of uniforms fit well throughout the test period. The fit preference for the Firewear uniform may be attributed to the softness of the blend material. The stiffness and boardiness of the FRT cotton uniform was a continual complaint.

Comfort - Fifty four percent of the participants preferred the comfort of the Firewear uniforms because the garment ensemble maintained its softness and comfort, was flexible and moved with the body, and felt cooler when worn in engineering spaces and/or while operating in warm environments. With regard to the FRT cotton work uniforms, the stiffness and boardiness of the material was a major complaint and the material did not soften up even after numerous shipboard launderings. Other complaints were that the FRT cotton material felt scratchy and to some it was "like wearing burlap or a cardboard box". In addition, several test participants complained of skin irritations after wearing the FRT cotton uniform. The majority of test participants strongly indicated that this uniform should not be pursued for a FR working uniform. In engineering spaces or working in seasonal warm environments, many respondents felt this uniform was too hot to work in.

Durability - Forty one percent of the test participants felt both uniforms were equally durable, did not show significant evidence of abrasion, rips or tears, etc., and held up quite well throughout the wear test period. The most significant problem was shirt buttons continually falling off and having to be resewn. The test participants who favored the FRT cotton uniforms for overall durability, commented that because the material appears heavier, stiffer, and thicker, the uniform should be more durable.

Appearance - Fifty eight percent of the test participants felt the Firewear uniform maintained a better appearance after continual wear and laundering, and was perceived to have good stain resistance and color retention. With respect to achieving a consistent professional look and military appearance, however, neither uniform held creases, and both wrinkled very easily and were extremely hard to iron by hand if not accomplished in the ship laundry. The FRT cotton uniform was particularly criticized for maintaining its hard wrinkled look, for remaining hard and stiff throughout the test period and for being almost impossible to iron out wrinkles even after one or two days of use.

Preference - Overall, the Firewear uniform was overwhelming preferred by 72% of the test participants because it felt softer and was more comfortable to wear. However, continual wrinkling and not holding a crease, were still major complaints.

CONCLUSIONS

Appearance was considered to be of extreme importance to Officers/CPO personnel. Based on response data, neither of these FR khaki uniforms was considered acceptable by evaluators with respect to maintaining a professional and military appearance. Both FR khaki uniforms fit well and neither showed any significant evidence of shrinkage. The softness of the Firewear material as compared to the stiffness and boardiness of the FRT cotton material, appeared to be a major contributing factor in perception of users that the Firewear uniform was more comfortable. Both FR uniforms were equally durable and held up well. It was quite evident that the participants perceived the FRT cotton garments to be more durable because the FRT cotton material felt heavier and stiffer. Neither uniform held a crease which was expected since they had no durable press finish.

TABLE VII

SUMMARY OF QUESTIONNAIRE RESPONSES FROM THE 110 RESPONDENTS

CHARACTERISTICS	100% FRT COTTON				FIREWEAR			
NUMBER OF DAYS WORN	1-5	6-15	16-30	>30	1-5	6-15	16-30	>30
# RESPONSES	14	35	33	28	9	23	41	37
AVERAGE NUMBER OF LAUNDERINGS	11/uniform				14/uniform			

NOTE: The following percentages represent the range of respondents favoring one uniform over the other for each characteristic.

CHARACTERISTIC	RESPONSES (%) 100% FRT COTTON	FIREWEAR	EQUAL
FIT AFTER REPEATED LAUNDERINGS	11	53	36
COMFORT	20	54	26
DURABILITY	37	22	41
APPEARANCE	19	58	23
PREFERENCE	20	72	8

RECOMMENDATIONS

Based on the laboratory materials evaluation and Shipboard wear trials, the Firewear uniform is recommended over the FRT cotton uniform for the FR CPO/Officer Khaki uniform. The Firewear materials performed better than the FRT cotton materials in the laboratory for overall durability, flame resistance, comfort and appearance. In fact, the FRT cotton materials failed flammability after multiple launderings. Since the requirement for shipboard laundering is 100 cycles, FRT cotton is therefore would be unacceptable for shipboard application. The shipboard wear trial further supports the recommendation. The Firewear uniform was overwhelmingly preferred over the FR cotton uniform.

An addendum report for fuel envelopment and garment impingement testing for these two fabrics is being finalized and will be forwarded.

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APPENDIX A

NAVY FORMULA II
HOT FORMULA (140°F) WITH OXYGEN BLEACH
CLASSIFICATION: Colored Cotton, Synthetic and Blended Fabrics - (Khaki Cotton, Certified Navy Twill & Blend Dungarees)

Step	Notes	Operation	Cycle Time (Minutes)	Water Temperature (Degrees Fahrenheit)	Water Level (Inches)	Supplies (100-lb Basis)
1	A	Break suds	10	140	4	16 oz detergent/ oxygen bleach
2		Drain	1			
3		Flush suds	6	140	4	
4		Drain	1			
5		Spin	1			
6		Rinse	3	140	4	
7		Drain	1			
8		Rinse	3	140	4	
9		Drain	1			
10	B	Sour	4	120	4	2.0 oz sour bacteriostat 12 oz instant starch
11		Drain	1			
12		Final Spin	4			

A. Detergent may be added directly to the wash once water level has been reached.

B. Add starch and run for 10 minutes in the manual mode when starch is required.

FOR SEAWATER WASHING

1. Use seawater in steps 1 and 3. Detergent bleach should be increased to 20 ounces.

2. Use fresh water in steps 6, 8, and 10.

APPENDIX B

APPENDIX B - UNIFORM DISTRIBUTION TO SELECTED TEST PARTICIPANTS ABOARD DESIGNATED EAST COAST SHIPS

	TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
		USS SHENANDOAH (AD-44)		
*	1	Large Shirt/34 Trousers	Male	Mainly work in office environment, working in Industrial area.
*	2	Large Shirt/36 Trousers	Male	Office work, repair lockers
**	3	36 Shirt/14 R Slacks	Female	Pump room and lots of washings
**	4	36 Shirt/14R Slacks	Female	Office work, repair lockers
	5	X-Large Shirt/38 Trousers	Male	-
		USS SCOTT (DDG-51)		
*	6	Large Shirt/36 Trousers	Male	Repairs on equipment,tours standing watches,tours through eng spaces
*	7	X-Large Shirt/34 Trousers	Male	Shipboard training on fire parties, patroling the ship
*	8	X-Large Shirt/34 Trousers	Male	Admin duties, fire drills
*	9	X-Large Shirt/38 Trousers	Male	Off loading supplies
	10	Large Shirt/34 Trousers	Male	-
	11	Large Shirt/34 Trousers	Male	-

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS ARLEIGH BURKE (DDG-51)		
* 12	Medium Shirt/32 Trousers	Male	Group Supervisor for Main Engine Room
* 13	Large Shirt/34 Trousers	Male	Mostly Admin work
* 14	X-Large Shirt/38 Trousers	Male	Engine work
15	Large Shirt/34 Trousers	Male	-
16	X-Large Shirt/34 Trousers	Male	-
	USS SHREVEPORT (LPD-12)		
* 17	X-Large Shirt/40 Trousers	Male	Supervisor of deck seamanship, Management of topside personnel
* 18	Medium Shirt/34 Trousers	Male	Bridge watchstanding Office work
* 19	Large Shirt/38 Trousers	Male	Deck work
* 20	Large Shirt/38 Trousers	Male	Machinery design, repairs to main propulsion machinery
* 21	Large Shirt/38 Trousers	Male	Command Master Chief, Duties all over ship, participating in various working parties
* 22	X-Large Shirt/38 Trousers	Male	Watchstanding
* 23	Large Shirt/36 Trousers	Male	Work with heavy equip.

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS ATLANTA (SSN 712)		
* 24	Medium Shirt/32 Trousers	Male	Supervisory & Maintenance
* 25	Large Shirt/36 Trousers	Male	Shipboard Admin duties
* 26	Medium Shirt/32 Trousers	Male	Supervisory and Admin. duties
* 27	X-Large Shirt/40 Trousers	Male	Operation maintenance, and supervisor of nuclear propulsion plant
* 28	Medium Shirt/32 Trousers	Male	In port working routine duties, including tours, sail closeout, etc.
* 29	Large Shirt/34 Trousers	Male	ER and Watchstanding
30	Medium Shirt/32 Trousers	Male	-
31	Large Shirt/34 Trousers	Male	-
	USS CINCINNATI (SSN-693)		
* 32	Large Shirt/36 Trousers	Male	Watchstanding in propulsion room.
* 33	Large Shirt/34 Trousers	Male	Supervising loading parts/food on and off ship
* 34	Large Shirt/36 Trousers	Male	Maintenance and Watchstanding.
* 35	X-Large Shirt/38 Trousers	Male	Admin, Guidance to topside personnel
36	Large Shirt/34 Trousers	Male	-
37	Large Shirt/34 Trousers	Male	-

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS WHIDBEY ISLAND (LSD-41)		
* 38	-	Male	Maintenance (working around grease)
* 39	-	Male	Hull repair shop
* 40	-	Male	Paint, grease, and dirt
	USS YELLOWSTONE (AD-41)		
** 41	36 Shirt/14 Slacks	Female	Work in hazmat material storage, storekeeper
* 42	Large Shirt/34 Trousers	Male	Supervisor of 16 welders, spent a lot of time in eng. spaces.
** 43	36 Shirt/14 Slacks	Female	Leading Chief for Electronics Space. Spent 50% of time running through spaces on ship.
* 44	Large Shirt/38 Trousers	Male	Food production, crews gallery
** 45	36 Shirt/12 Slacks	Female	Normal office type work, I did wear the uniforms a lot to do repair work.
46	Large Shirt/34 Trousers	Male	-
47	Medium Shirt/36 Trousers	Male	-

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS AMERICA (CV-66)		
* 48	-	Male	Division Officer duties of walking through spaces, Supervising personnel
* 49	Large Shirt/34 Trousers	Male	Watchstanding, work inspections
* 50	Medium Shirt/34 Trousers	Male	Desk work, troubleshooting, and repair of mechanical systems in main propulsion spaces
* 51	X-Large Shirt/34 Trousers	Male	Flight Deck
* 52	Large Shirt/34 Trousers	Male	Flight deck operations and major catapult arresting gear maintenance.
* 53	Medium shirt/32 Trousers	Male	Inspecting tanks and office work
* 54	Large Shirt/36 Trousers	Male	Eng inspections, watchstanding
* 55	Medium Shirt/32 Trousers	Male	Main propulsion space watchstanding, Space inspections.
* 56	X-Large Shirt/38 Trousers	Male	Refueling, Painting, boat operations
* 57	Large shirt/36 Trousers	Male	Engine Room Inspections, watchstanding

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS FITZGERALD (DDG-62)		
* 58	-	Male	Office Work, shipboard tours
* 59	X-Large Shirt/36 Trousers	Male	Mainly supervisory work
* 60	-	Male	Office Work, Ship visiting
* 61	Large Shirt/31 Trousers	Male	Office duties, onboard ship functions
* 62	X-Large Shirt/36 Trousers	Male	Admin in office equipment, touring ship spaces under construction
* 63	X-Large Shirt/36 Trousers	Male	Touring ship, inspections, etc.
* 64	-	Male	Industrial work/tours
* 65	X-Large Shirt/36 Trousers	Male	Admin in office environment, touring eng spaces and training
	USS HOIST (ARS-40)		
66	Large Shirt/34 Trousers	Male	-
67	Medium Shirt/36 Trousers	Male	-
68	Large Shirt/36 Trousers	Male	-
69	Medium Shirt/34 Trousers	Male	-
70	Large Shirt/34 Trousers	Male	-

Note: Ship decommissioned during the evaluation period.

APPENDIX B - UNIFORM DISTRIBUTION TO SELECTED TEST PARTICIPANTS ABOARD DESIGNATED WEST COAST SHIPS

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS CONSTELLATION (CV-64)		
* 71	Medium Shirt/34 Trousers	Male	Administrative
* 72	Large Shirt/32 Trousers	Male	Engineering(Overhaul of propulsion turbine, V-2 Maintenance)
* 73	Medium Shirt/32 Trousers	Male	P-1 (Working on boilers and pumps, lots of grease and dirt)
* 74	Medium Shirt/34 Trousers	Male	V-2 (catapult arresting gear maintenance, handling hydraulic and grease in atmosphere)
* 75	Large Shirt/34 Trousers	Male	V-1 flight deck operations
* 76	Large Shirt/34 Trousers	Male	Plumbing, Welding, etc.
	USS DENVER (LPD-9)		
* 77	X-Large Shirt/34 Trousers	Male	Crane operations, boat operations
* 78	X-Large Shirt/40 Trousers	Male	Fire Marshal Inspections, Supervisor of machinery personnel
* 79	Medium Shirt/34 Trousers	Male	Admin, Fire Part Training
* 80	Large Shirt/36 Trousers	Male	Machinery maintenance
* 81	Large Shirt/36 Trousers	Male	Fire drills, maintenance
* 82	Large Shirt/36 Trousers	Male	Maintenance
* 83	X-Large Shirt/36 Trousers	Male	Minor machinery repair

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS CALLAGHAN (DDG 994)		
* 95	Large Shirt/34 Trousers	Male	Working outside on CIWS, Shipyard environment
* 96	Large Shirt/34 Trousers	Male	Gunners mate, hydraulic repair, etc.
* 97	X-Large Shirt/36 Trousers	Male	Division Officer, System training of piping, Inspecting eng spaces.
98	Large Shirt/36 Trousers	Male	-
* 99	Medium shirt/34 Trousers	Male	Ship tours, eng. inspections
* 100	Medium Shirt/34 Trousers	Male	Engineering, Gas turbine Supervisor
	USS CHANCELLORSVILLE (CG 62)		
* 101	Medium shirt/32 Trousers	Male	Supervisor of 52 personnel employed in paint and preservation duties throughout the ship
* 102	Medium Shirt/36 Trousers	Male	Worked on missile launchers, Gun mounts, crane operations, etc.
* 103	Large Shirt/34 Trousers	Male	Maintenance in electrical cooling and radar systems
* 104	Medium Shirt/32 Trousers	Male	Worked on steam system, moving equipment down slim stairwells
* 105	Large Shirt/38 Trousers	Male	Supervisor of engine room maintenance
* 106	large Shirt/36 Trousers	Male	Pump overhaul, admin duties, general equipment repair

TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
	USS FORT FISCHER (LSD 40)		
* 107	Medium Shirt/34 Trousers	Male	Admin, Maintenance Eng. Supervisor, Equipment Inspection
* 108	X-Large Shirt/40 Trousers	Male	Watchstanding, going through hatches and scattles
* 109	Medium shirt/34 Trousers	Male	Watchstanding, Main in main machinery spaces
* 110	Medium Shirt/34 Trousers	Male	Watchstanding, machinery space
* 111	Large Shirt/36 Trousers	Male	Office, Eng Room Training
* 112	Medium Shirt/34 Trousers	Male	Mechanical work
* 113	Medium Shirt/34 Trousers	Male	-
	USS KINCAID (DD 965)		
* 114	Medium Shirt/34 Trousers	Male	Daily work in eng spaces, and rountinely on equip while wearing uniforms
* 115	Medium Shirt/34 Trousers	Male	Maintenance on auxiliary equipment, Admin duties
* 116	Large Shirt/34 Trousers	Male	Overhauled motors, worked on switch gears
* 117	Large Shirt/36 Trousers	Male	Maintenance and repair of ships auxiliary equip
* 118	X-Large Shirt/38 Trousers	Male	Inspect machinery spaces, fire fighting
* 119	X-Large Shirt/36 Trousers	Male	Combat info, watchstanding, electronics repair work
* 120	X-Large Shirt/40 Trousers	Male	Touring inspection all eng spaces, flight deck officer

	TEST SUBJECT #	SIZE OF SHIRT/ TROUSERS ISSUED	M/F	TYPE OF WORK PERFORMED
		USS COMSTOCK (LSD 45)		
*	121	Medium Shirt/32 Trousers	Male	Admin duties
*	122	Medium Shirt/34 Trousers	Male	Fire drills
*	123	Medium Shirt/32 Trousers	Male	Well deck operations
*	124	Medium Shirt/34 Trousers	Male	Eng work in main spaces
	125	Large Shirt/32 Trousers	Male	-
	126	Medium Shirt/32 Trousers	Male	-
		USS CHANDLER (DDG 966)		
*	127	X-Large Shirt/36 Trousers	Male	Admin, occassional handling of firefighting equipment, and wear of FF ensemble over both khaki uniforms
*	128	Medium Shirt/34 Trousers	Male	Admin, maintenance
*	129	X-Large Shirt/38 trousers	Male	Engine Room
		USS CAPE COD (AD 43)		
**	130	36 Shirt/14 Slacks	Female	Inspection of shipboard repairs, office management
	131	34 Shirt/12 Slacks	Female	-
	132	36 Shirt/12 Slacks	Female	-
	133	34 Shirt/12 Slacks	Female	-

* 104 of the 124 Male Participants Responded

** 6 of the 9 Female Participants Responded

APPENDIX C

NAME/RATE: ----------

SHIP: ----------

DIVISION: ----------

CODE LETTER OF
UNIFORM ON GARMENT
LABEL: A w/red tag B

EVALUATION DATE: START: ---------- FINISH ----------

1. Briefly describe the major type of work duties performed while wearing the uniform.

---

2. Approximate the number of days each uniform was worn during this test period.

	1 to 5	6 to 15	16 to 30	Over 30
A	------	--------	---------	--------
B	-------	--------	---------	---------

3. How many times did you shipboard launder each of the uniforms ?

A ---------- B ----------

4. Which uniform fit the best after repeated laundering (please circle) ?

A B Equal

Please comment ----------

---

5. Which uniform was more comfortable (please circle) ?

A B Equal

Please comment ----------

---

6. Which uniform was more durable to abrasion, rips or tears, etc. (please circle) ?

A B Equal

Please comment ----------

---

7. Which uniform had the best appearance after repeated wear and cleaning (please circle) ?

A B Equal

Please comment ----------

---

8. Which of the two uniforms did you prefer (please circle) ?

A B

9. List any comment both positive or negative in regard to the uniforms worn.

A

B

Signed ----------

Date ----------

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